FINAL REPORT

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DYNAMICS OF NEAR SHORE ICE

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CONTENTS

I. Summary

The near shore pack ice of the Beaufort Sea and Chukchi Sea have a profound influence on the development of the gas and oil fields of Northern Alaska. Design of structures, security of sub-surface pipelines, and surface transport of oil is dependent on a knowledge of many of the properties of the near shore pack ice. The motion of the ice pack has been investigated over the past several years. From October 1975 to December 1976 OCSEAP sponsored a number of drifting buoys initially deployed along the continental shelf from Banks Island to Pt. Barrow. In the spring of 1977 a number of drifting buoys were deployed in the central Chukchi Sea. In the spring of 1978 four buoys were deployed in the near shore ice pack from Pt. Barrow to Cape Lisburne. This final report is of the motion of the four buoys deployed in 1978.

The study of the ice pack can be undertaken from a number of different views. Of primary importance is an observational program oriented toward a description of the state and motion. Other methods of study include the description of physical processes, often through mathematical modelling, and the development of various simulations, important to forecasting the state of the ice pack. The primary task of this contract is to observe the motion of the near shore pack ice from Pt. Barrow to Cape Lisburne. This program expands the geographic coverage and offers some indication of year-to-year variability of -the ice behavior.

Previous studies have shown the near shore ice between the Mackenzie Delta and Pt. Barrow tends to be guided by the coast in its westward drift. Oil or other pollutants entered into the pack ice would probably be advected to some location off Pt. Barrow. Then depending on local conditions the pack can move northward and be reincorporated into the Beaufort Gyre or it can move southward, still guided by the Alaska coast, into the Chukchi Sea. The current studyshowsthe near shore ice pack between Pt. Barrow and Cape Lisburne to move into the central Chukchi Sea during early summer and then to move north and west; probably to be incorporated into the transpolar drift stream. Once the ice moved toward the central Chukchi the mean motion was very similar to the drift of the summer of 1977.

II. Introduction

A. General Nature and Scope of Study

The purpose of the project was to determine from drifting buoys the motion of the near shore ice pack from Pt. Barrow to Cape Lisburne. In March of 1978, four RAMS (Random Access Measurement System) buoys were deployed within 100 km of the coast. This study extends the geographical area and provides some indication of year-to-year variations of the motion of sea ice. Of particular importance is the relation between the buoys and the margin between the pack ice and season open water. Also of interest is the frequency of very high speed events along the coast as observed in January of 1976. At this time one buoy recorded speeds to 140 cm see-l and net motions of several hundred kilometers within a week's time.

B. Specific Objectives

The primary objective of this report is to present the motion of the four buoys during March - October 1978. One buoy was instrumented with a barometer to record surface atmospheric pressures. This time series is also reported.

C. Relevance to Problems of Petroleum Development

Observations of ice motions are relevant to problems of petroleum development for three broad reasons: 1) the ice cover will serve as a carrier of any petroleum products spilled in the Beaufort or Chukchi Sea so that the ice trajectories serve as a first estimate of the paths to be taken by the oil 2) the observations are necessary to identify the important physical processes at work within the ice pack and 3) the ice motion is an observable quantity that may be compared with a simulation of pack ice dynamics or used to tune the simulation.

III. Current State of Knowledge

The RAMS buoys are reliable off-the-shelf items at a reasonable cost ($5000) and usually survive for the design life of the batteries. The NIMBUS satellite relays data between the buoy and NASA data processing. The data processing of the NASA data tapes is a capability to be developed at each user's site. The University of Washington has the data processing capability.

The buoys deployed in March 1978 are the third set deployed as part of OCSEAP . The first set provided drift data in the southern Beaufort Sea in conjunction with the AIDJEX project during October 1975 - December 1976. These trajectories were reported in the 1977 Annual Report, Vol. XVI, by Untersteiner and Coon (RU 98). The second set were deployed in the central Chukchi Sea during March 1977 - September 1977 and the data is given in the Annual Report 1978 by Pritchard. The buoys reported here were deployed in the Chukchi Sea near the Alaskan coast in March 1978. Other ice drift data are the ice island T-3, the ship *Maud*, and a number of the Soviet North Pole ice stations.

IV. Study Area

The study area is the Chukchi Sea with emphasis on the near shore ice pack.

V. Sources, Methods, and Rationale of Data Collection

The measurements were made with the Random Access Measurement System (RAMS) which uses the techniques of Doppler Satellite navigation. The raw measurement is the frequency of a signal transmitted from the ice station to the satellite. The measured frequency is affected by a Doppler shift related to the rate of change in distance between the satellite and the ice station, which is itself related to the unknown ice coordinates and the known satellite orbit. During each satellite orbit several frequency measurements were made and from them an

over-determined solution was found for the unknown coordinates. The Doppler counts were made for discrete l–second bursts transmitted from the buoy each minute. Typically, 20 measurements per pass were collected, stored, and transmitted to a receiving station on the ground. Fix calculations were done at NASA and mailed to the users in the form of magnetic tapes and printed output .

The user must edit the data for bad position fixes. The algorithm employed compares each fix latitude with the median of the latitude of the ten fixes preceding and the ten fixes following it. When the differences exceed a preset tolerance, the fix is discarded. The algorithm is applied twice, with a smaller tolerance the second time. The same procedure was then applied for longitude.

The barometer was a Paroscientific Digiquartz sensor having superior accuracy, low sensitivity to temperature and low power consumption. This type of barometer has previously been used with RAMS buoys. The frequency of the quartz oscillator is encoded, radioed to the NIMBUS satellite, relayed to NASA, and later decoded by the user. Calibration charts are used to convert the frequency to atmospheric pressure.

VI. Results

Positions of the four buoys deployed in March 1978 have been edited. The results are shown in Figures 1-4 and in Appendix I. Figures 1-4 show at most one position fix per day as indicated by the small ticks. The large dots show the position near the first of each month.

The data was collected by the NIMBUS 6 satellite. The testing and launching of the NIMBUS 7 satellite disrupted the NASA data collection center. Over some periods the data was lost and over much of the time beginning in August the data was not available on magnetic tapes. By September the number of fixes was down to one every other day. This is in contrast to the usual number of twenty per day for the period March - June. Hand analysis provided the position data shown by the solid line in Figures 1-2.

The lifetime of the buoys was five to seven months. All available data is shown. Figure 5 shows the position of the ice edge for the summer of 1978. The ice edge analysis was obtained from NOAA satellite images.

VII. Discussion

The trajectories of the buoys are northward and westward during the spring and summer months. This is in accordance with the climatological drift as evidenced by T3, *Maud*, and several Soviet ice stations. The speed and direction of the 1978 buoys is very similar to the speed and direction of the 1977 buoys . It is interesting to note that the slight motion toward the Bering Straits during March was also seen in the 1977 buoy data.

A comparison of the drift data and the ice edge charts indicates that the buoys were always in the multi-year ice zone. Figures 1–5 suggest the ice edge is drivin by the winds rather than a result of simple thermodynamics.

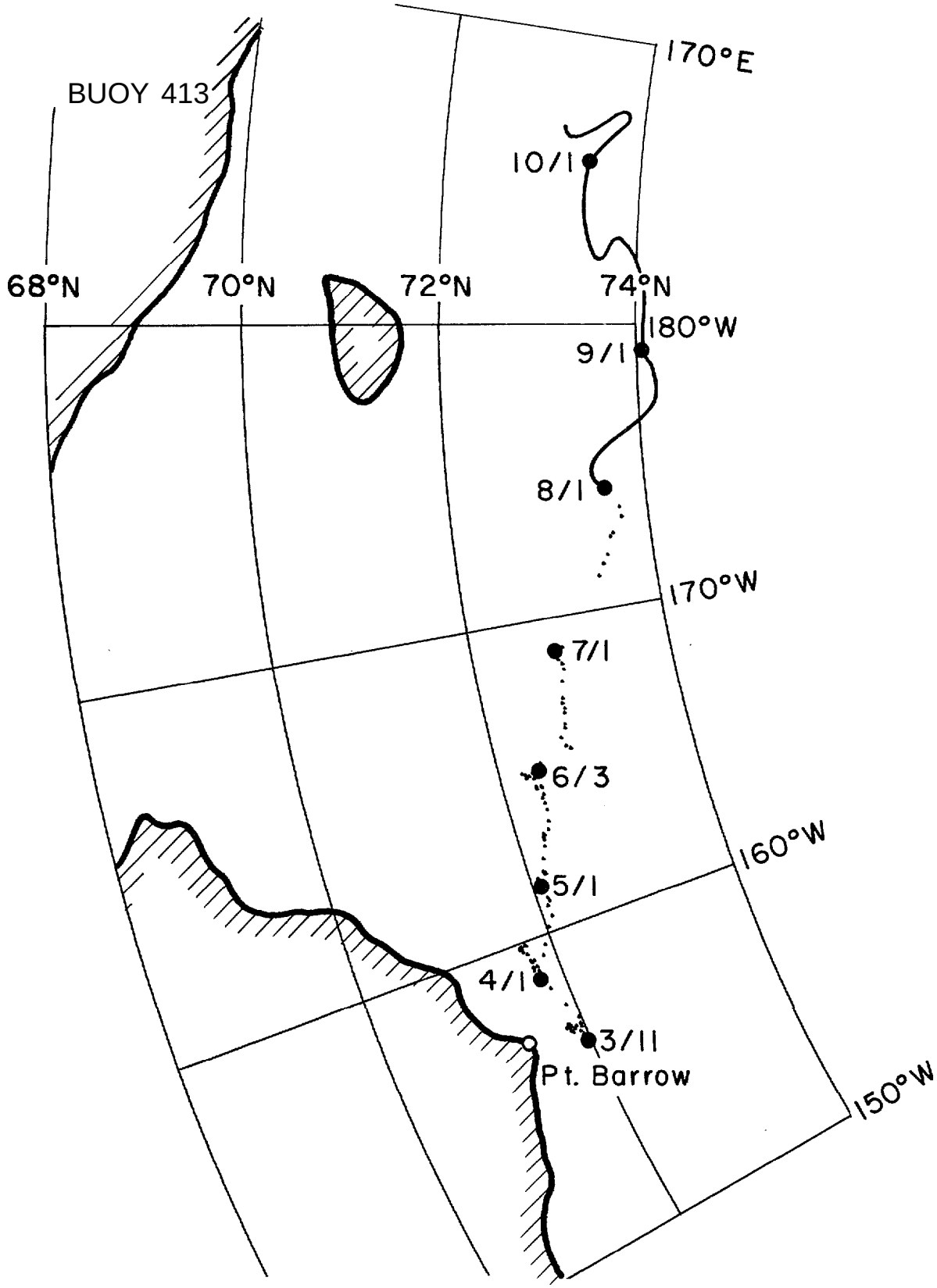


Figure 1: Trajectory of buoy 413

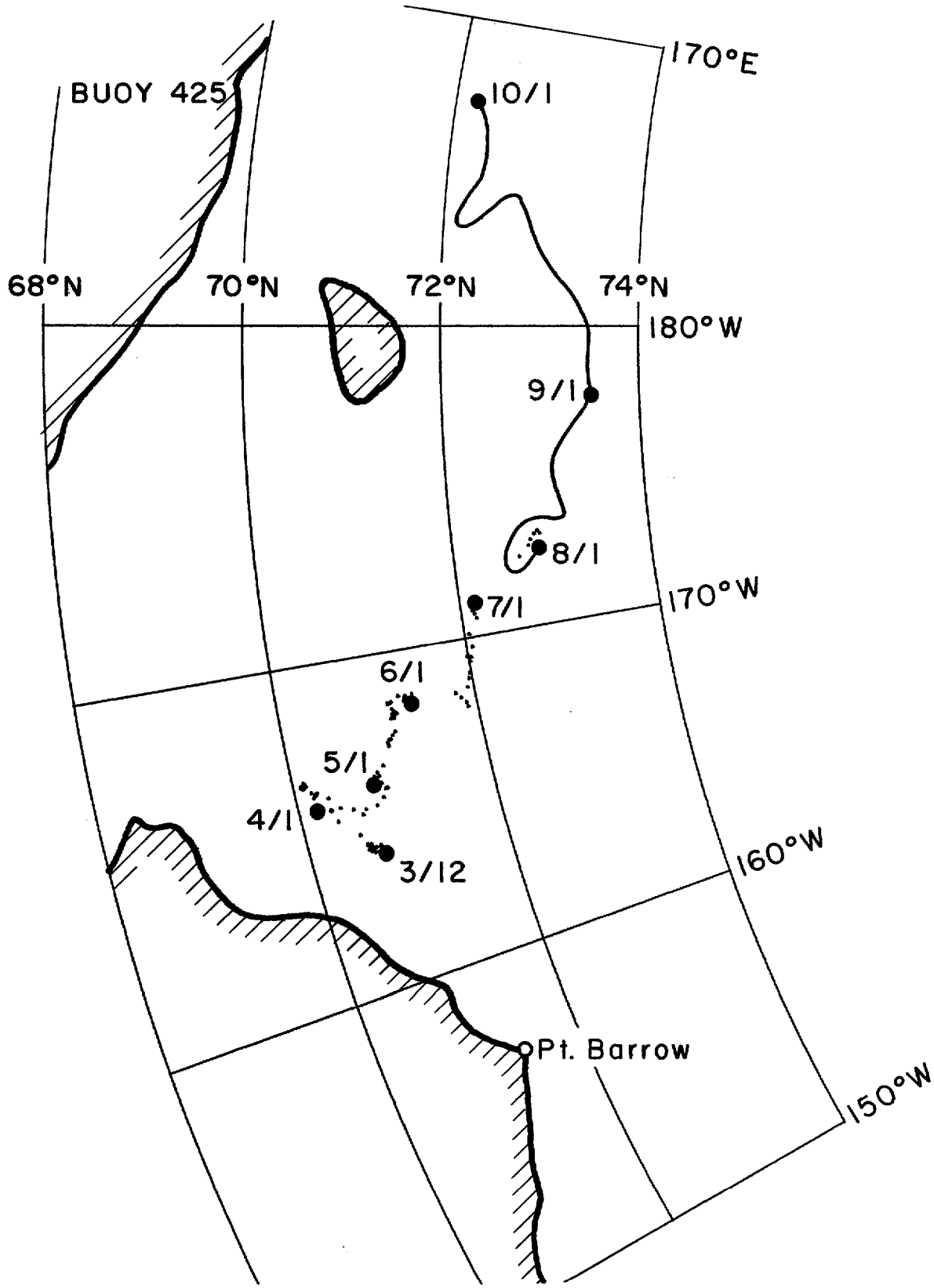


Figure 2: Trajectory of buoy 425.

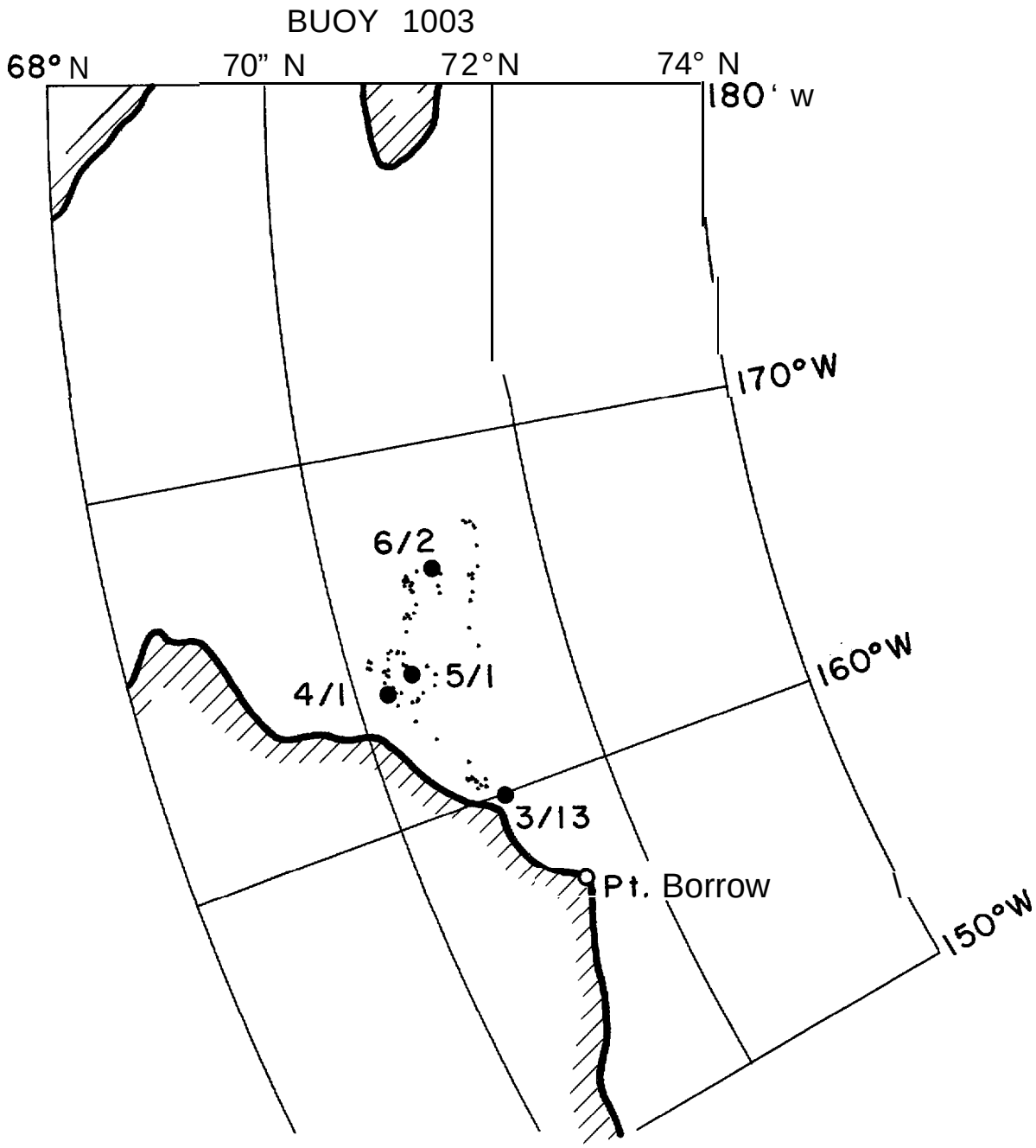


Figure 3: Trajectory of buoy 1003.

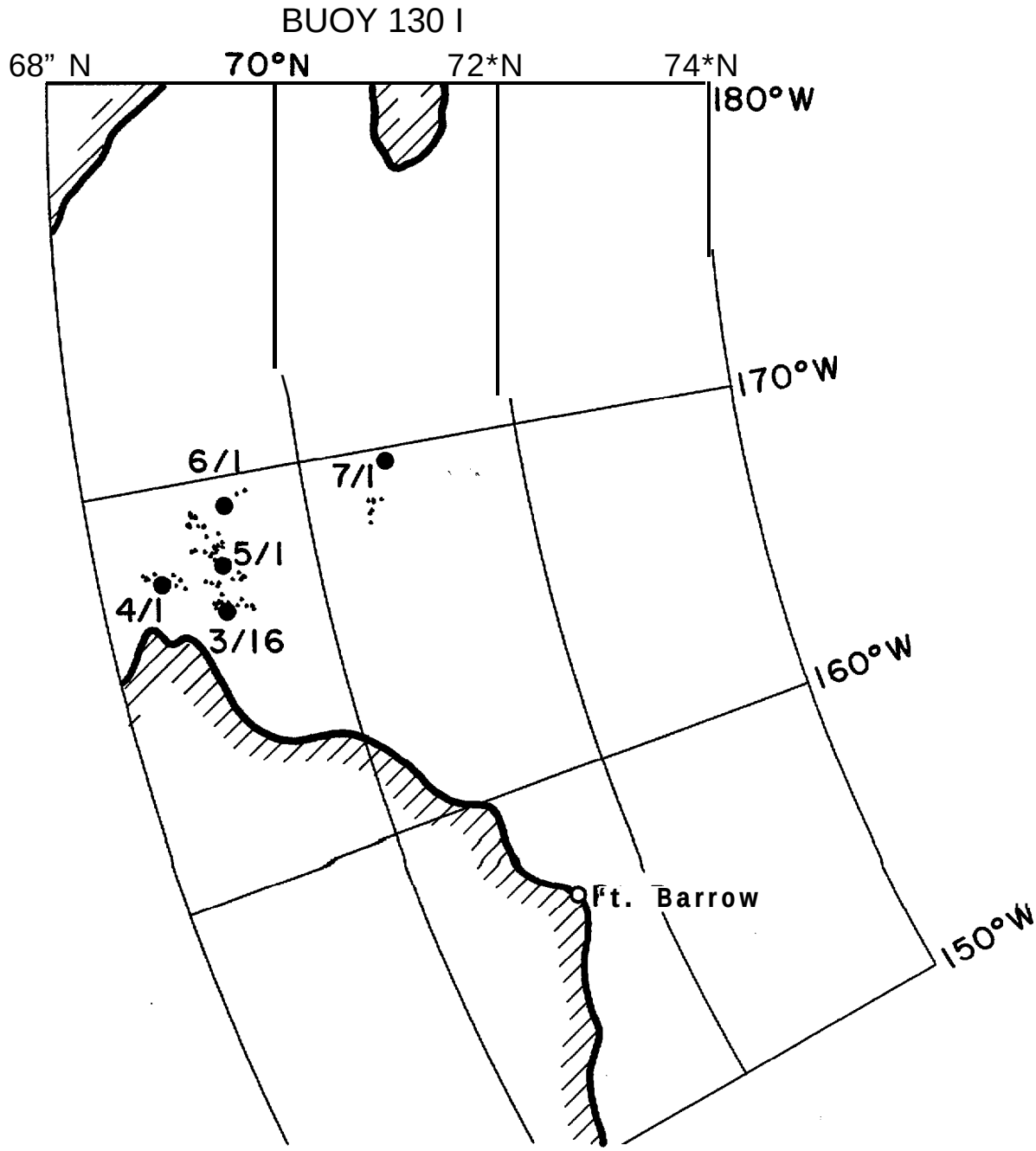


Figure 4: Trajectory of buoy 1301,

Oil spilled in the pack ice between Pt. Barrow and Cape Lisburne would be of no danger to Bering Sea for the year 1978. Although it is known that some ice from the Chukchi Sea has drifted through the Bering Straits and into the Bering Sea, this is not the norm. The years 1976-1978 all show the same summertime drift features; however sea ice is well known for producing anomolous events. The data of 1977-78 does not show the large jets of near shore pack ice motion that was recorded in January of 1976.

VIII Conclusions

Drift of the ice cover in the Chukchi Sea during March - October 1978 has been determined. The general northward and westward motion would have precluded oil spilled on or in the ice from being transported into the Bering Sea at this time. The drift for this time is very similar to the drift reported in 1977. The probable fate of the buoys is to be incorporated into the transpolar drift stream and exit into the Greenland Sea after two or three years.

DYNAMICS OF NEAR SHORE ICE

APPENDIX I

Measurements of Sea Ice Motion in the Chukchi Sea March-October 1978.

Four data buoys were deployed in the Chukchi Sea in March of 1978. Data has been processed to obtain position. Due to the preparation and launch of the NIMBUS 7 satellite some of the position data was analyzed by hand. The solid curves in the following figures indicate that analysis. The automatic data processing is described in AIDJEX Bulletin No. 35 by A. S. Thorndike and J. Y. Cheung (January 1977, University of Washington). The atmospheric surface pressure recorded at Buoy 425 is also reported in this appendix.

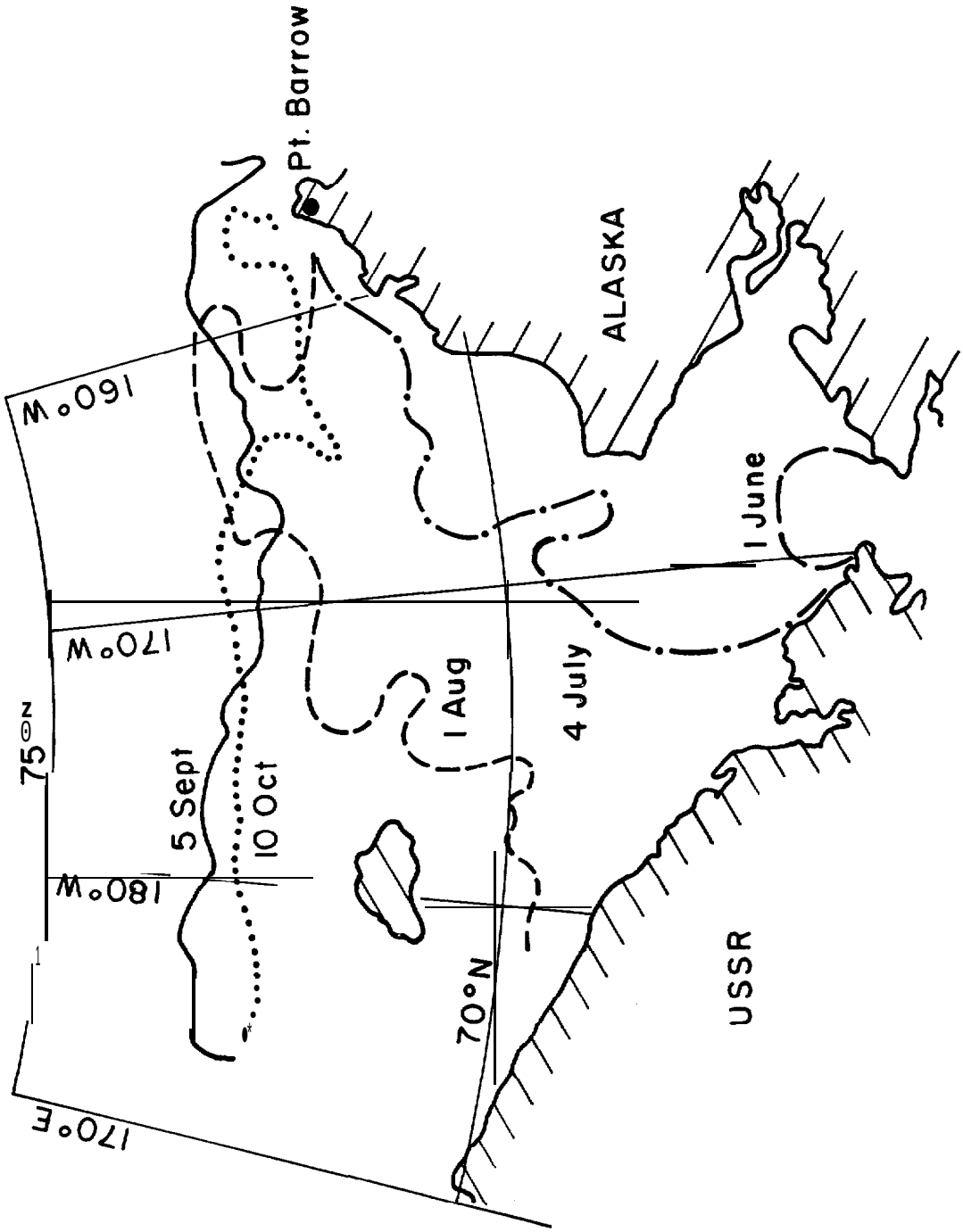
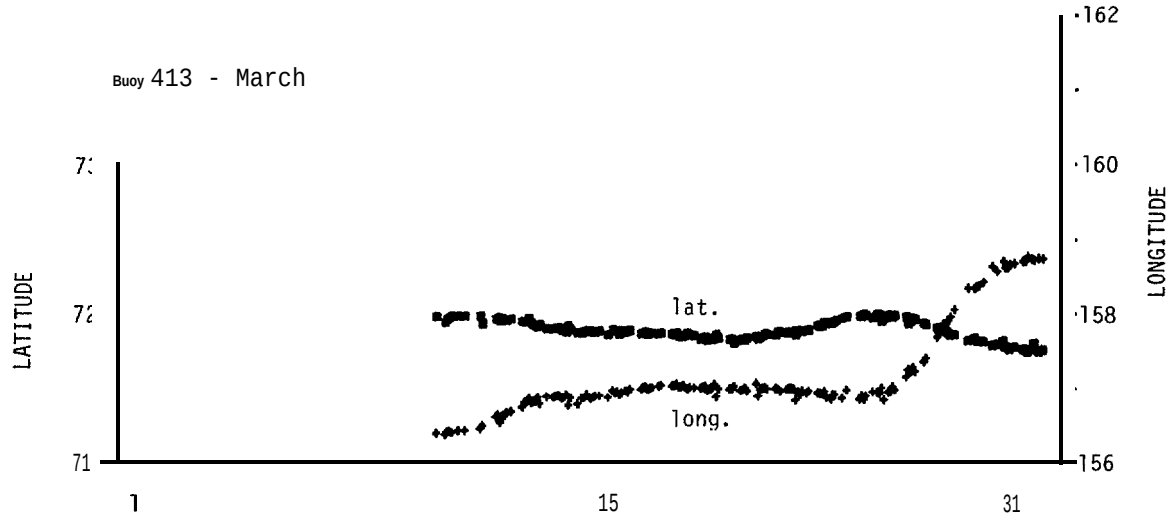


Figure 5: Ice edge margin from NOAA images, Summer 1978.


Buoy 413 - March
LATITUDE
LONGITUDE
lat.
long.
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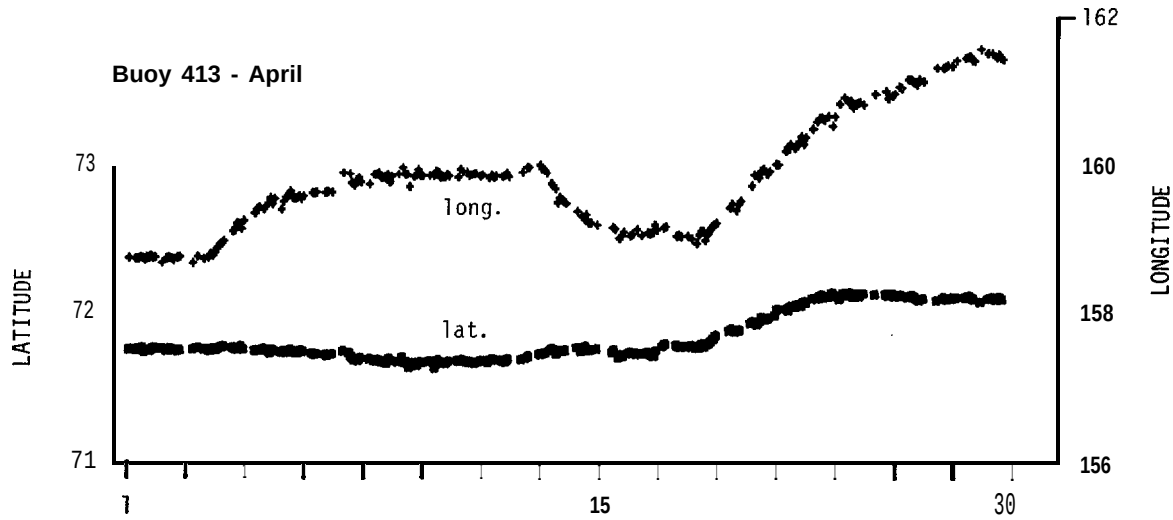
72
73
156
158
160
162
1
15
31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LONGITUDE
long.
lat.
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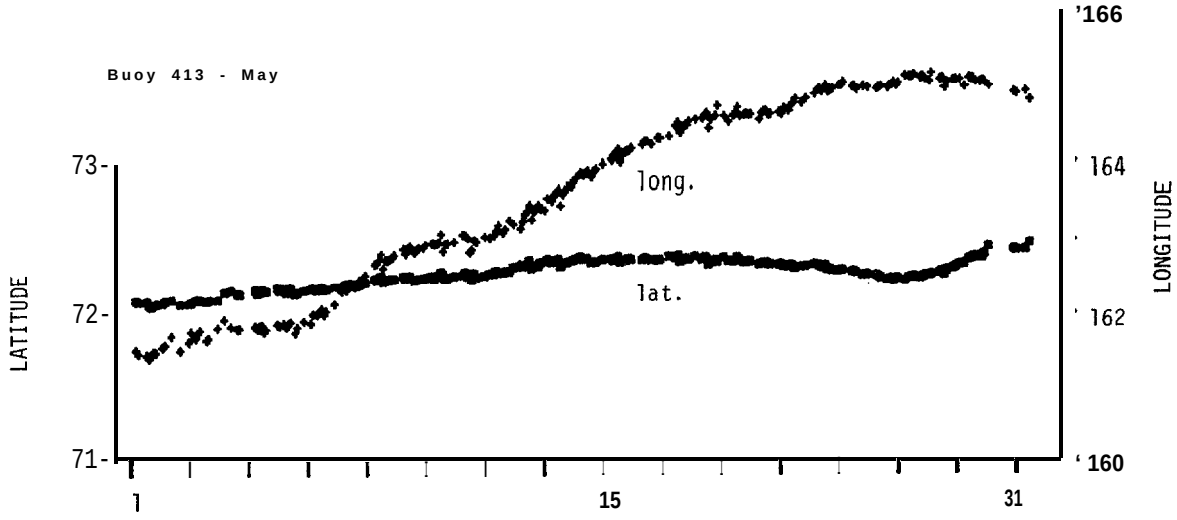
72
73
156
158
160
162
1
15
30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LONGITUDE
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lat.
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164
166
1
15
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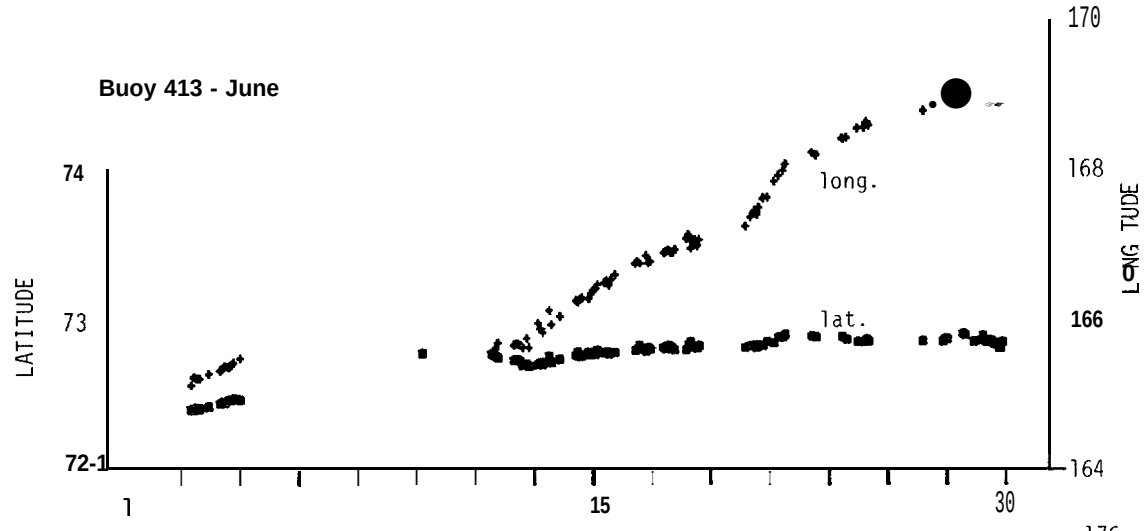
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long.
lat.
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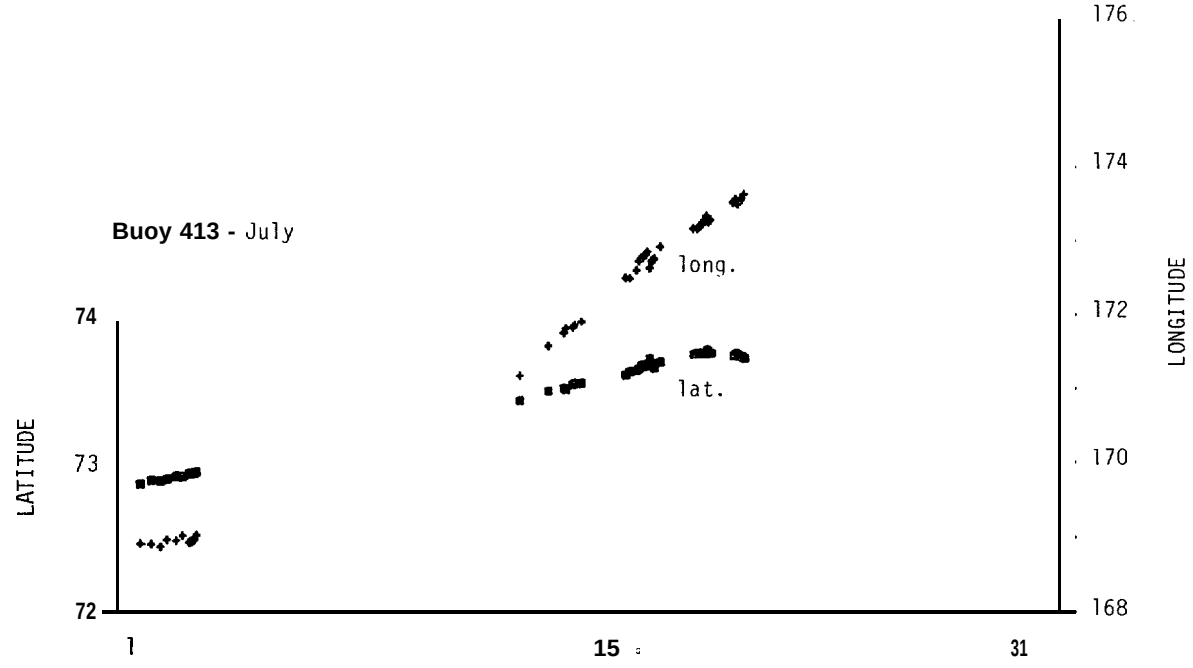
168
166
164
LONG TUDE
1
15
30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lat.
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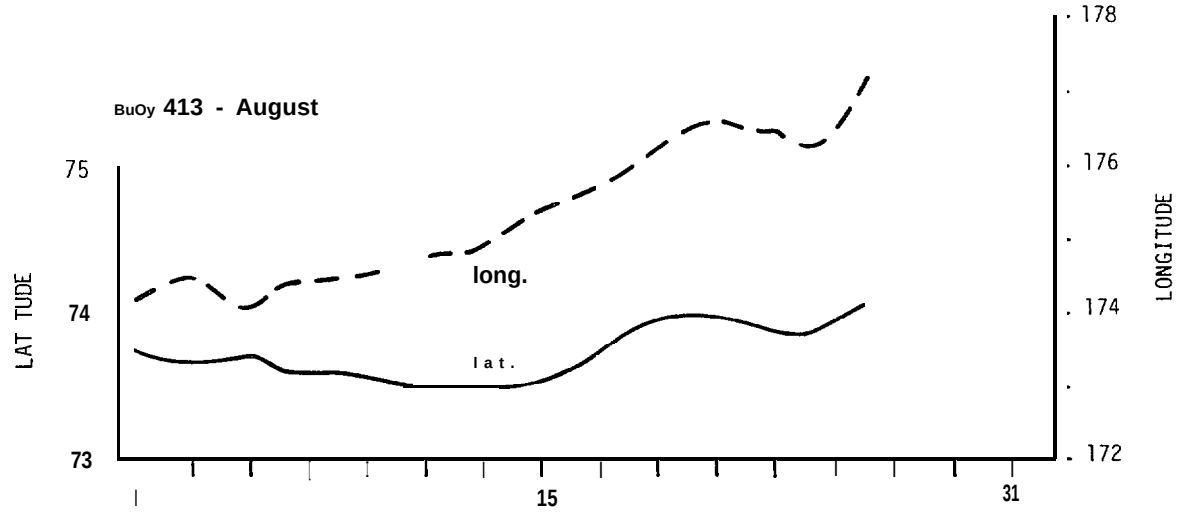
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lat.
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LONGITUDE
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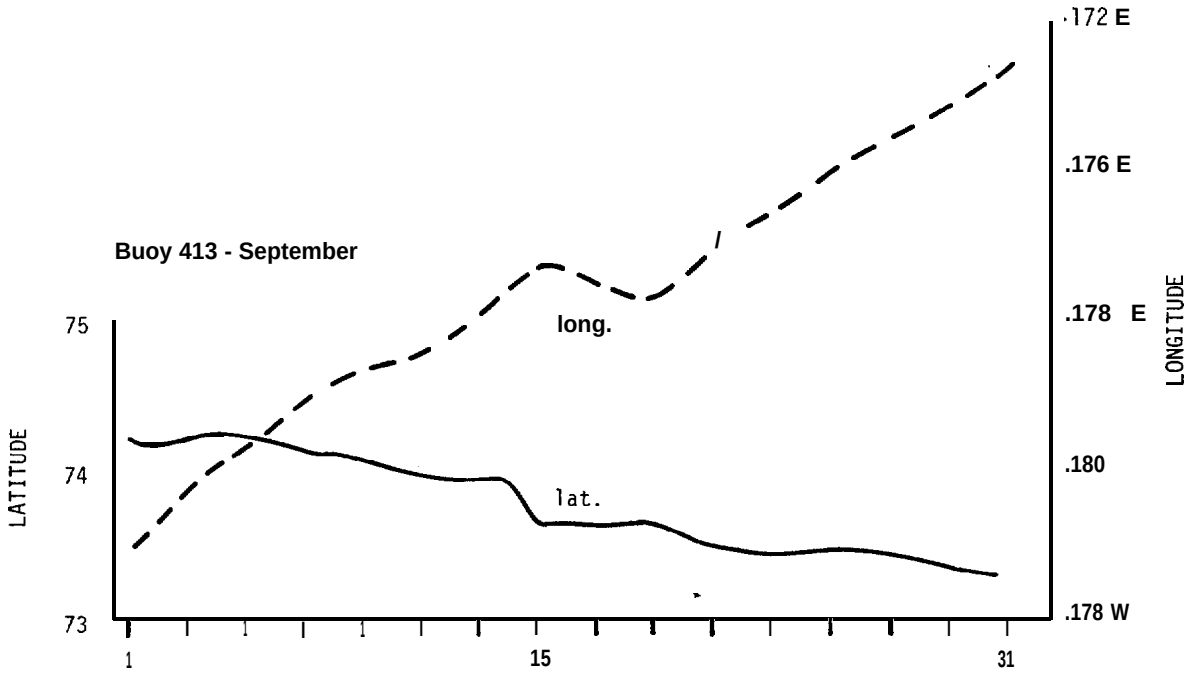
Buoy 413 - September
long.
lat.
LATITUDE
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15
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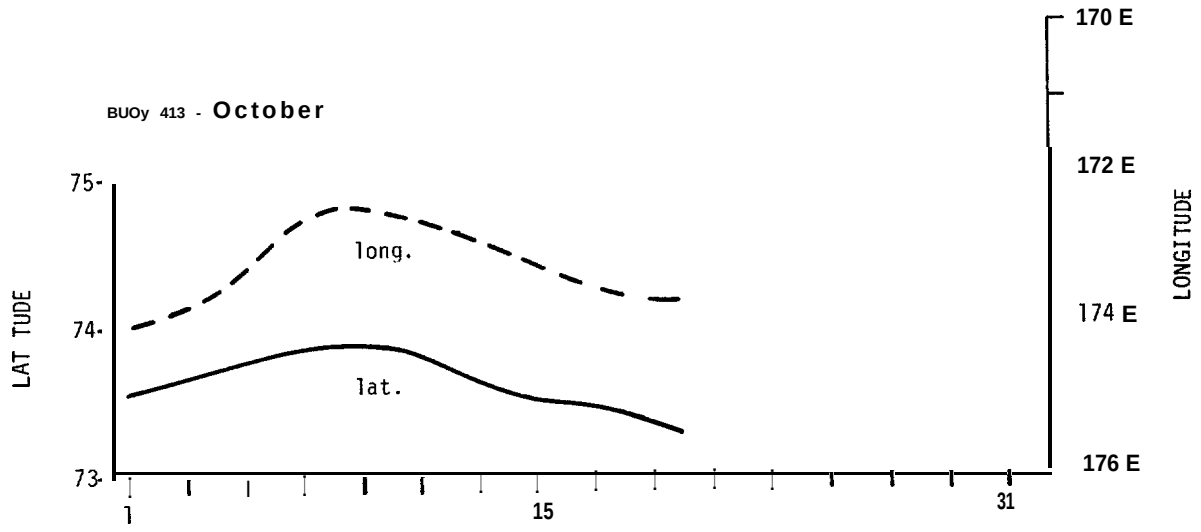
172 E
176 E
178 E
180
178 W
LONGITUDE


BUOy 413 - October
long.
lat.
LAT TUDE
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74
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170 E
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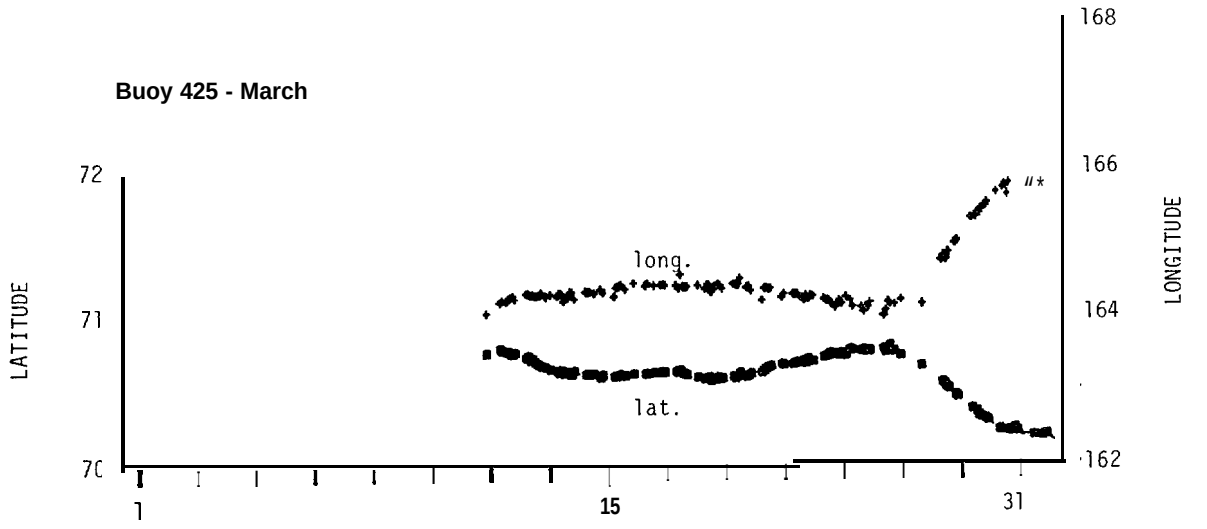
174 E
176 E
LONGITUDE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LONGITUDE
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lat.
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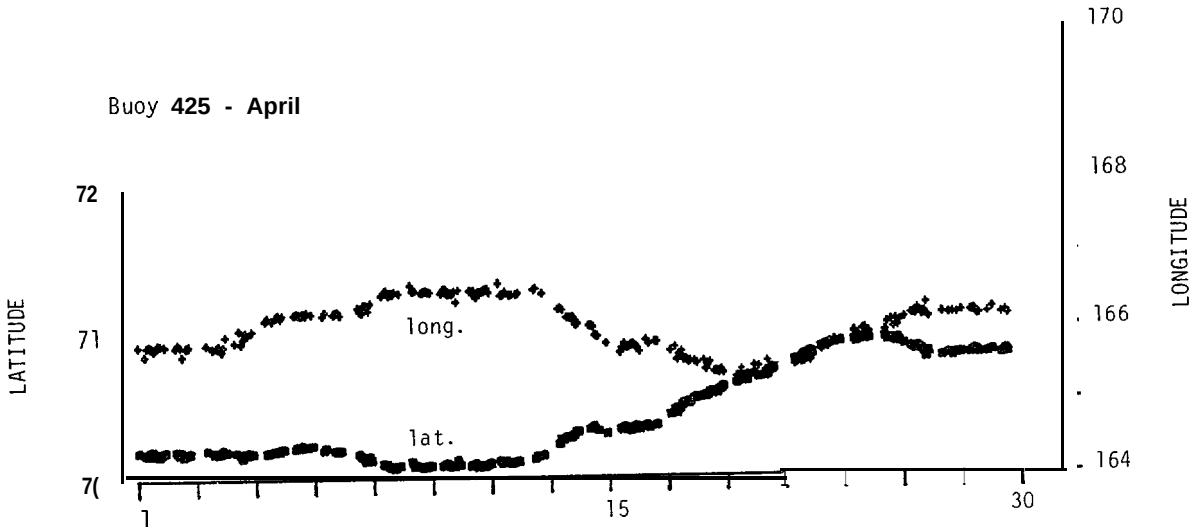
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LONGITUDE
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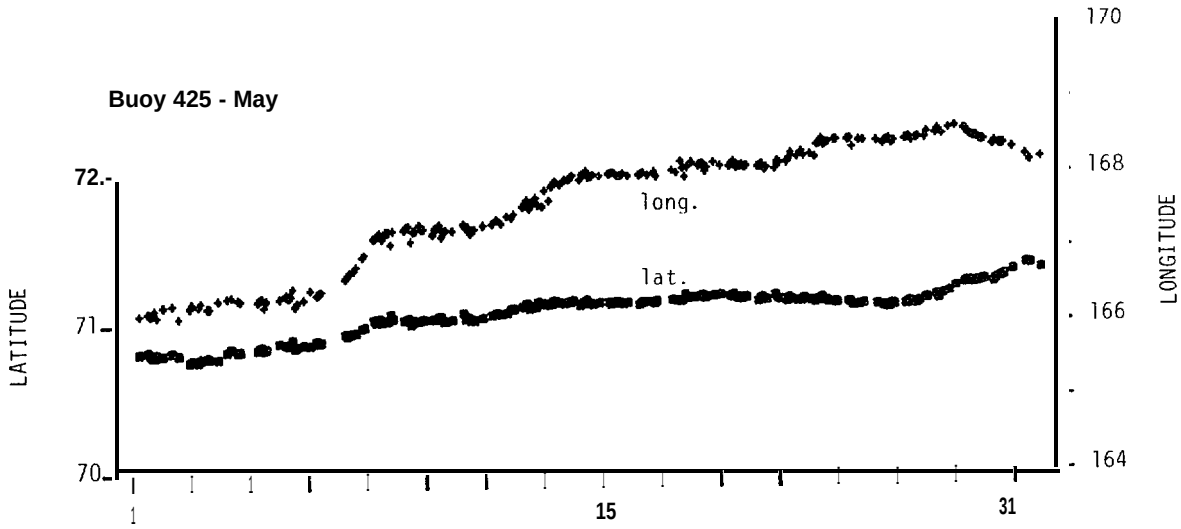
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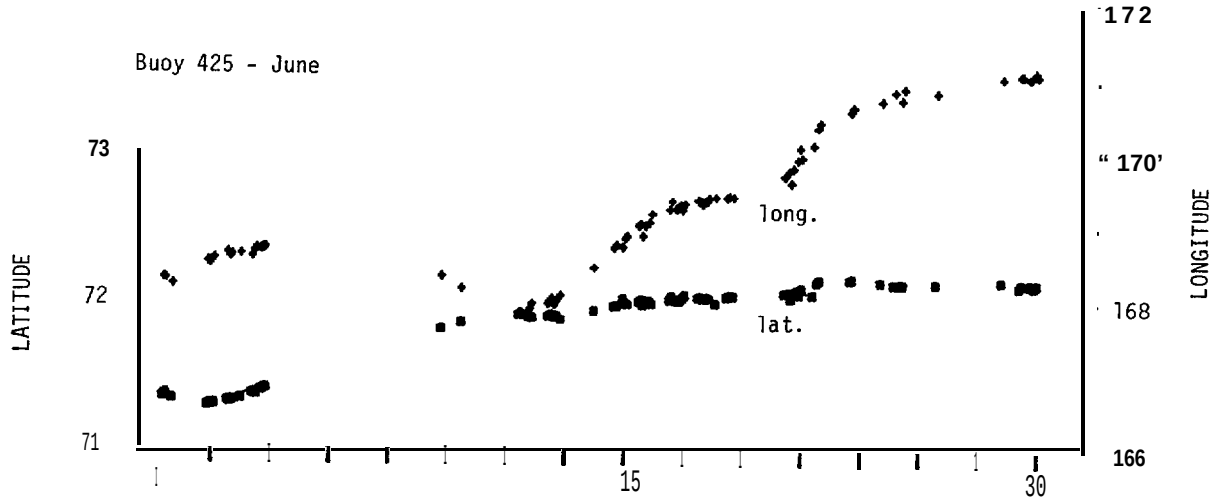
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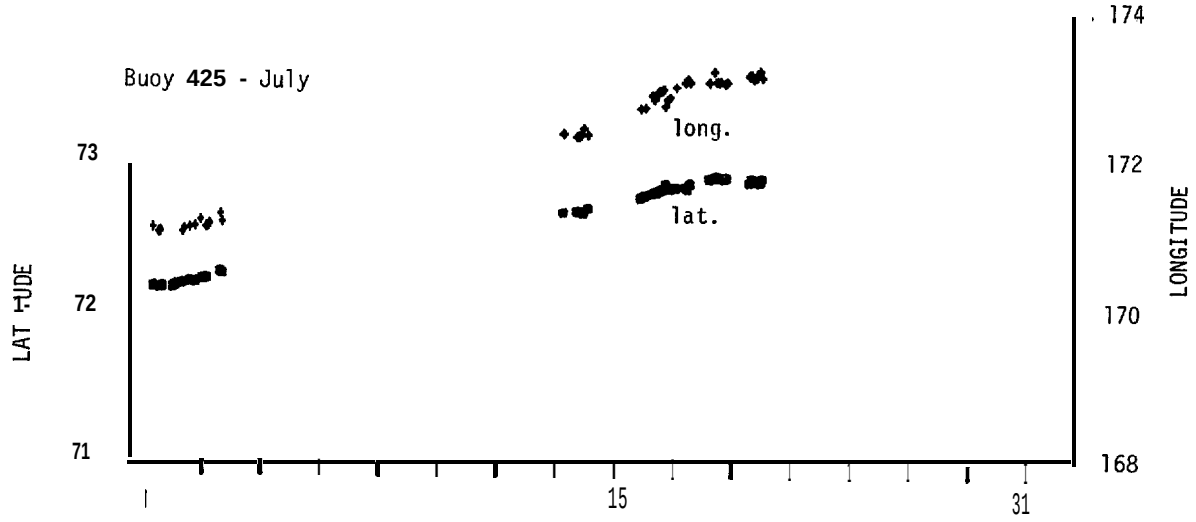
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LONGITUDE
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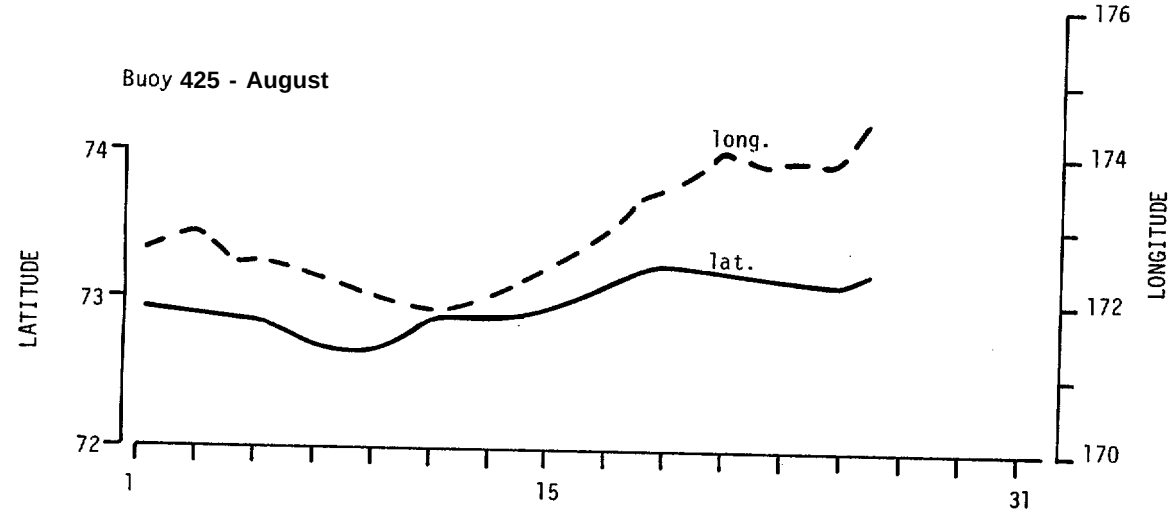
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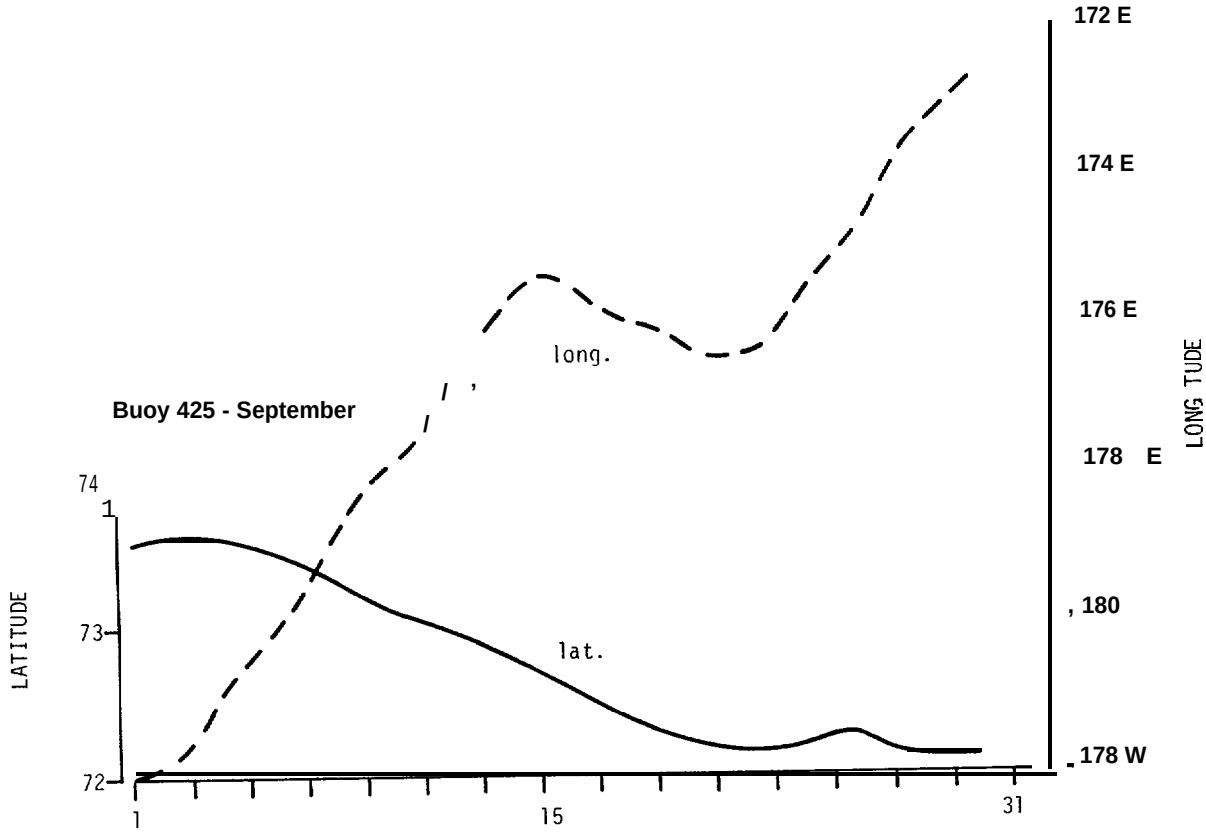
Buoy 425 - September
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lat.
LATITUDE
LONG TUDE
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172 E
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178 E
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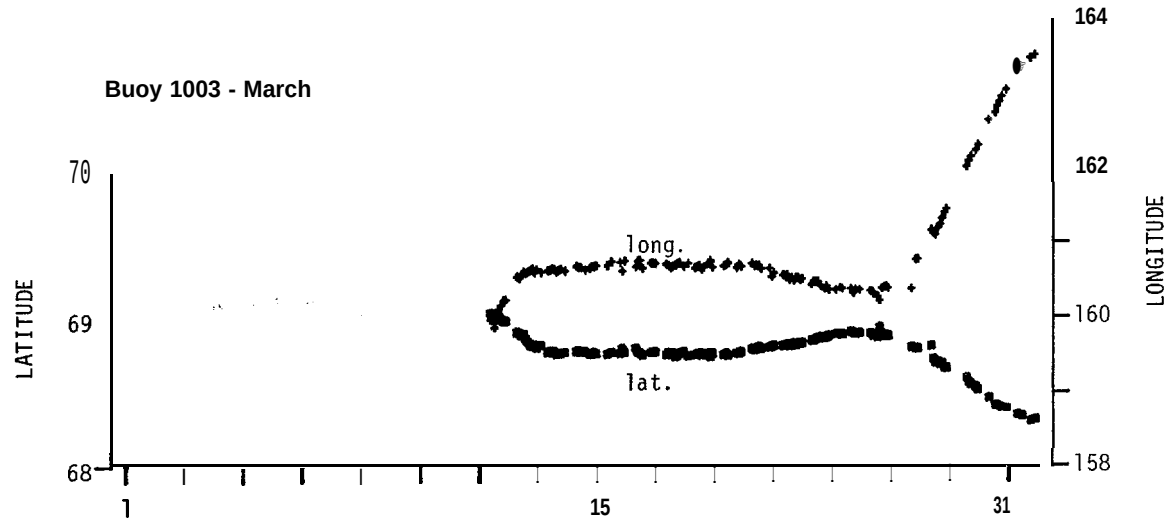
178 W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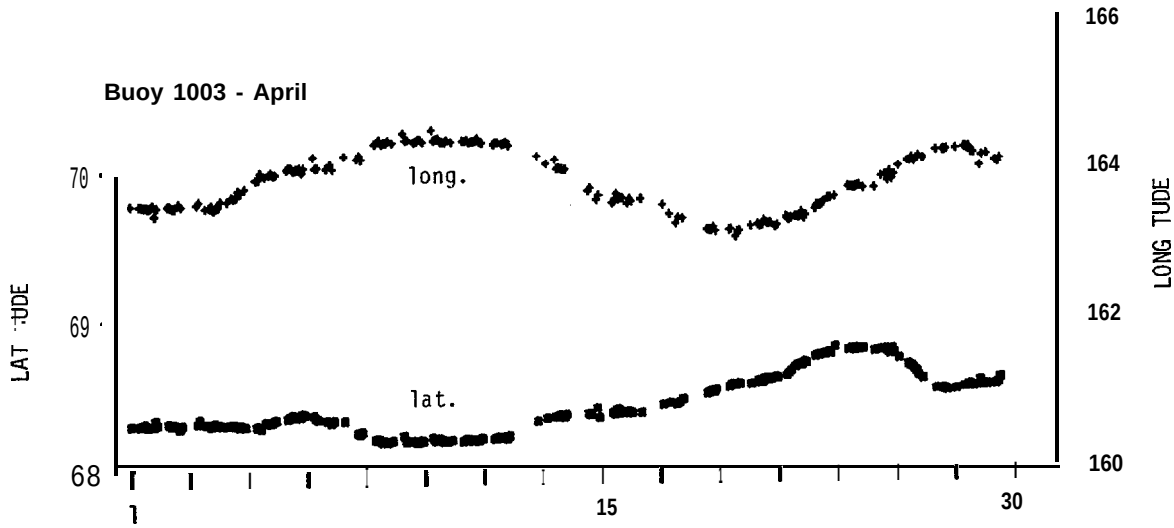
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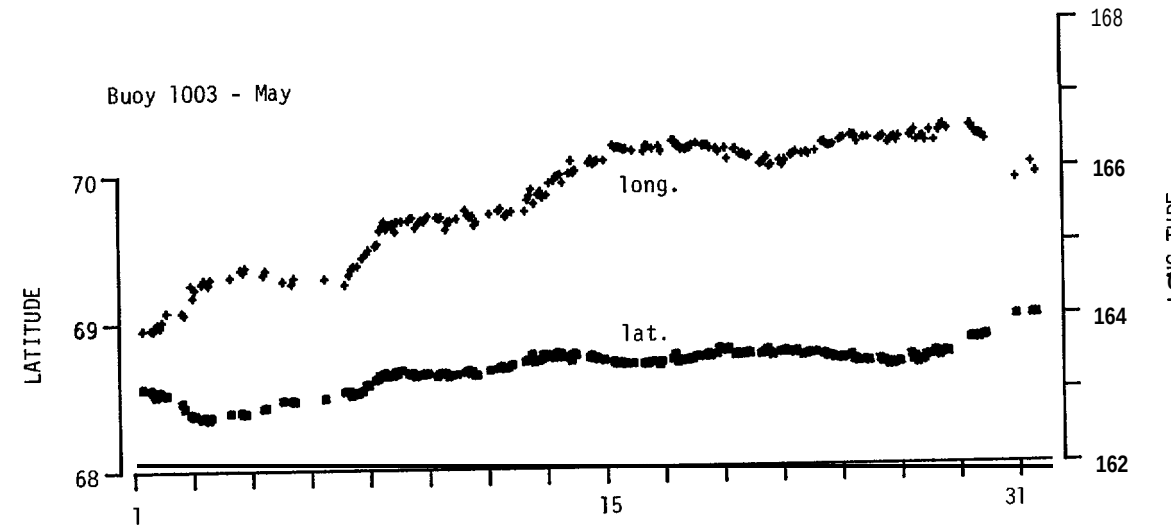
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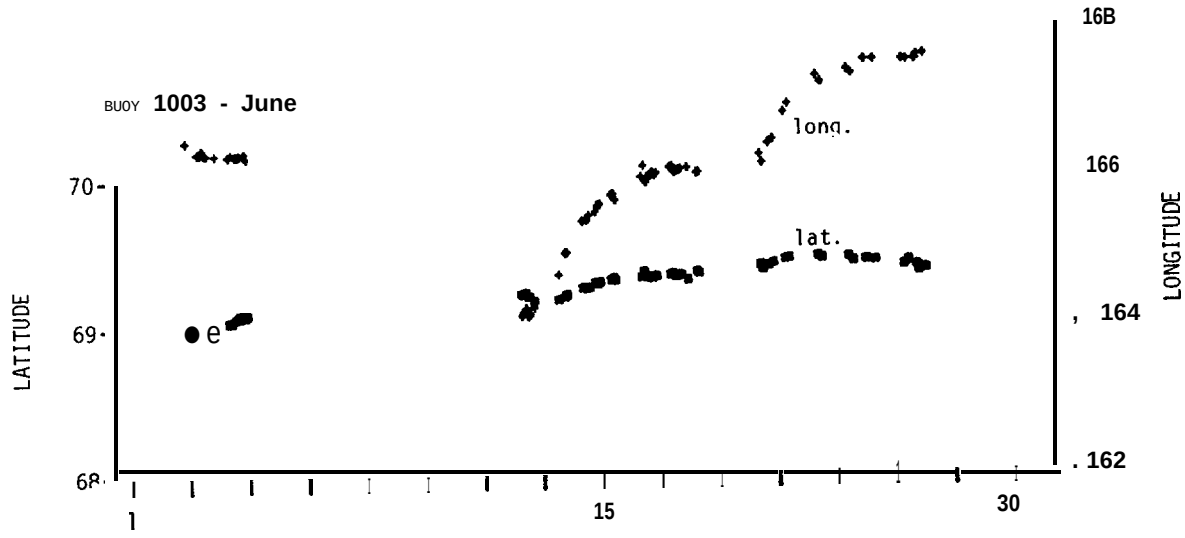
BUOY 1003 - June
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lat.
LATITUDE
LONGITUDE
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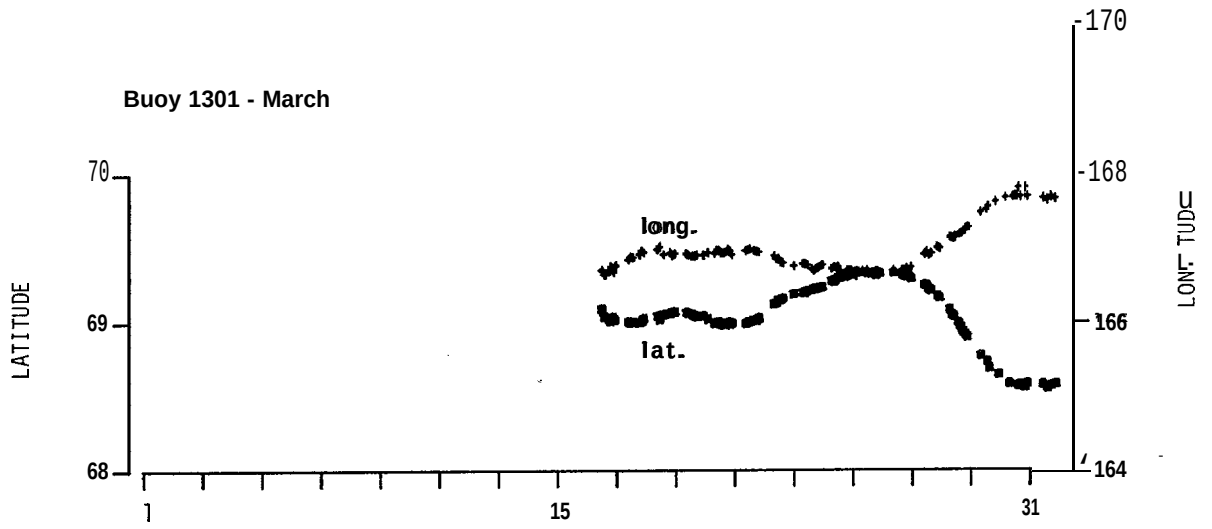
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-168
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164
long.
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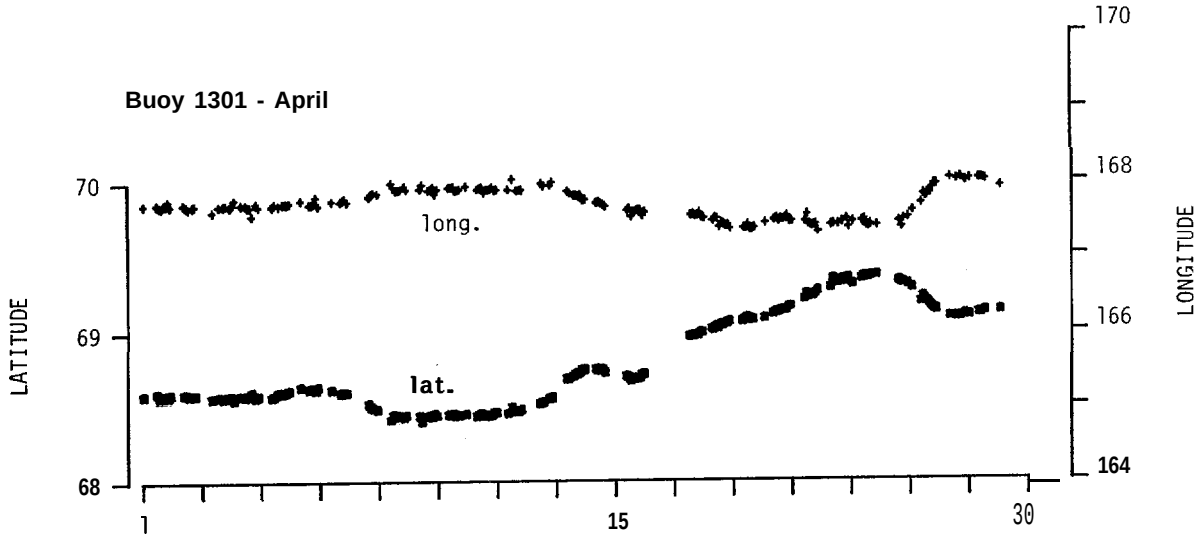
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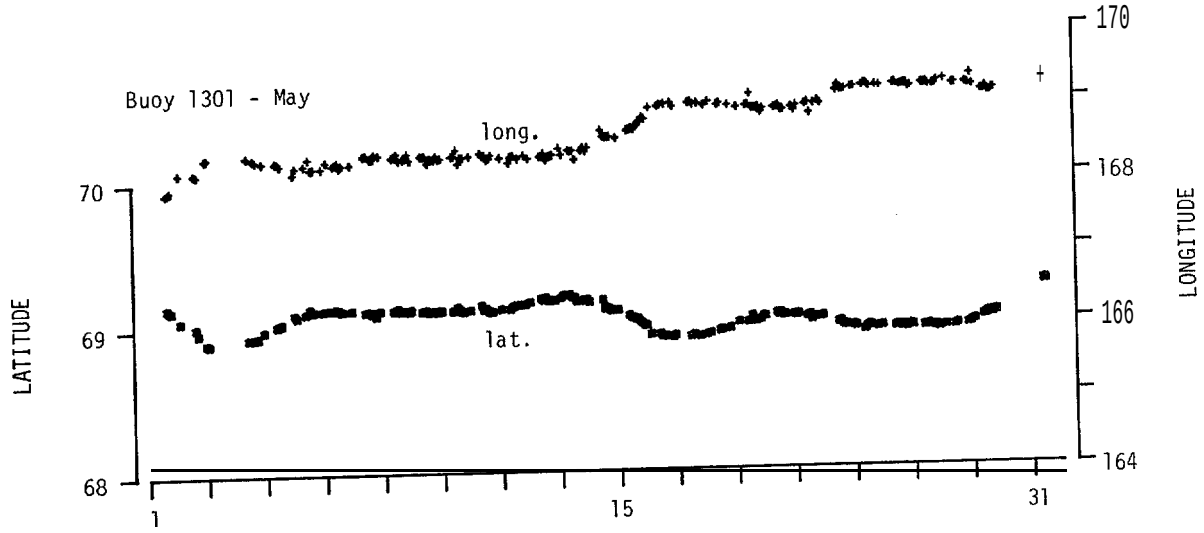
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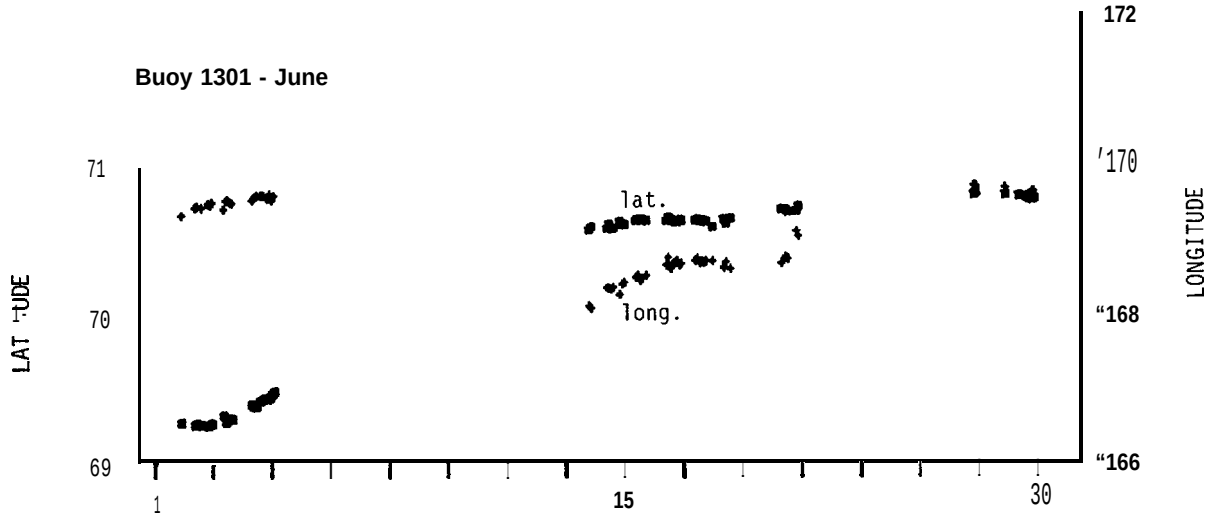
Buoy 1301 - June
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70
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LAT TUDE
lat.
long.
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'170
"168
"166
LONGITUDE
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15
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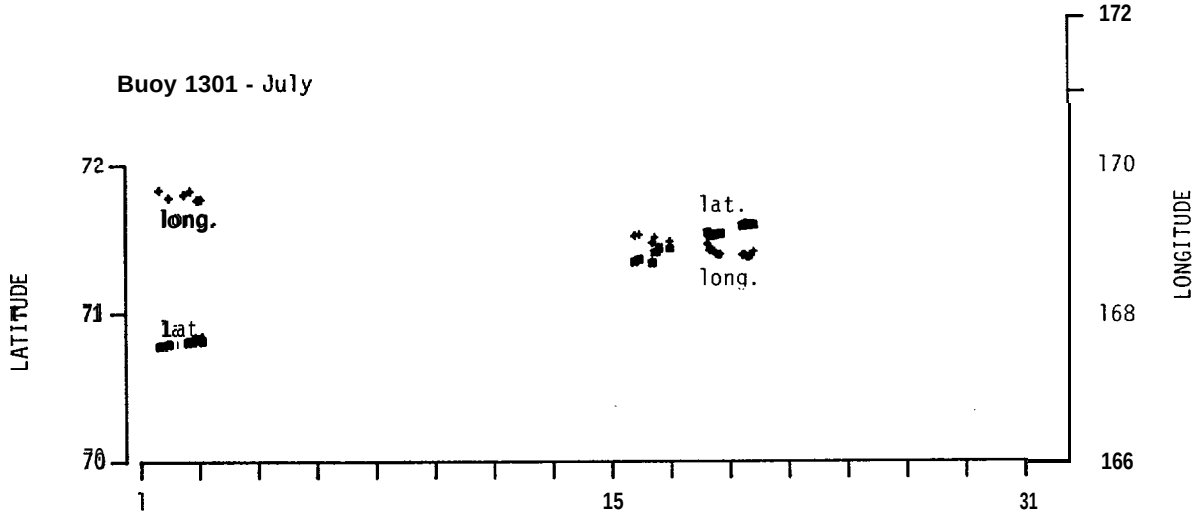
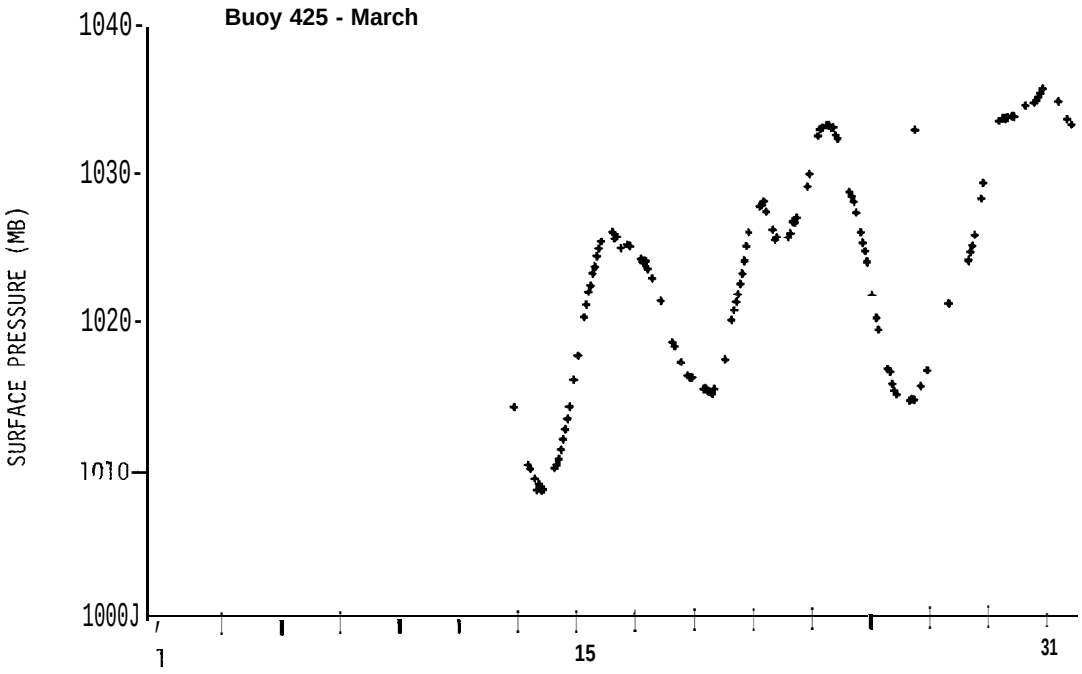
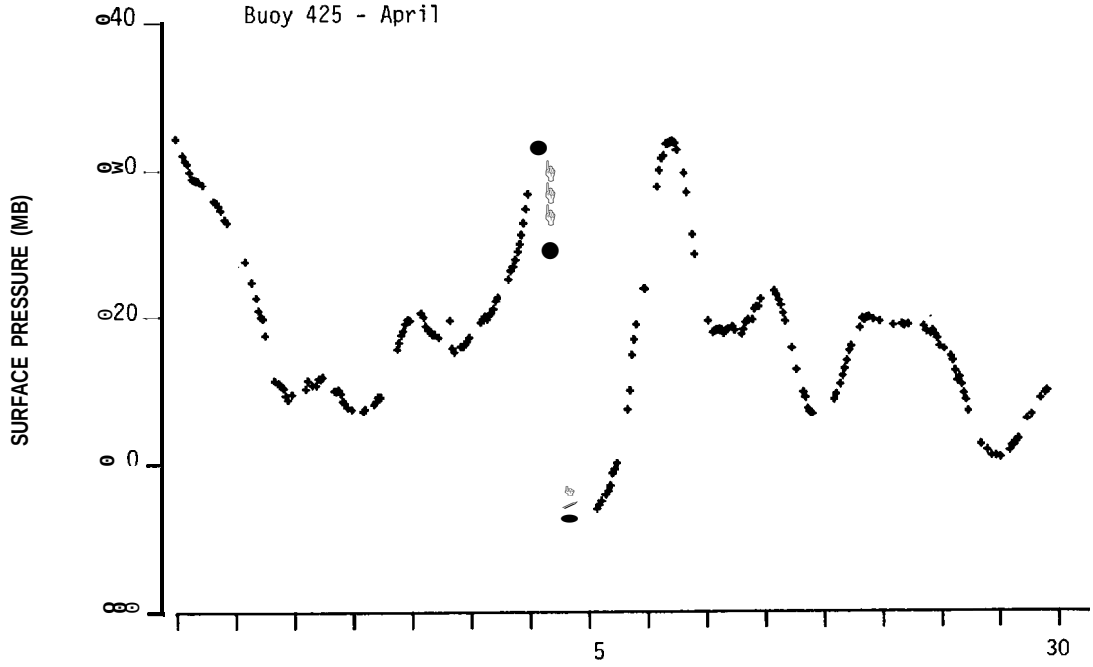
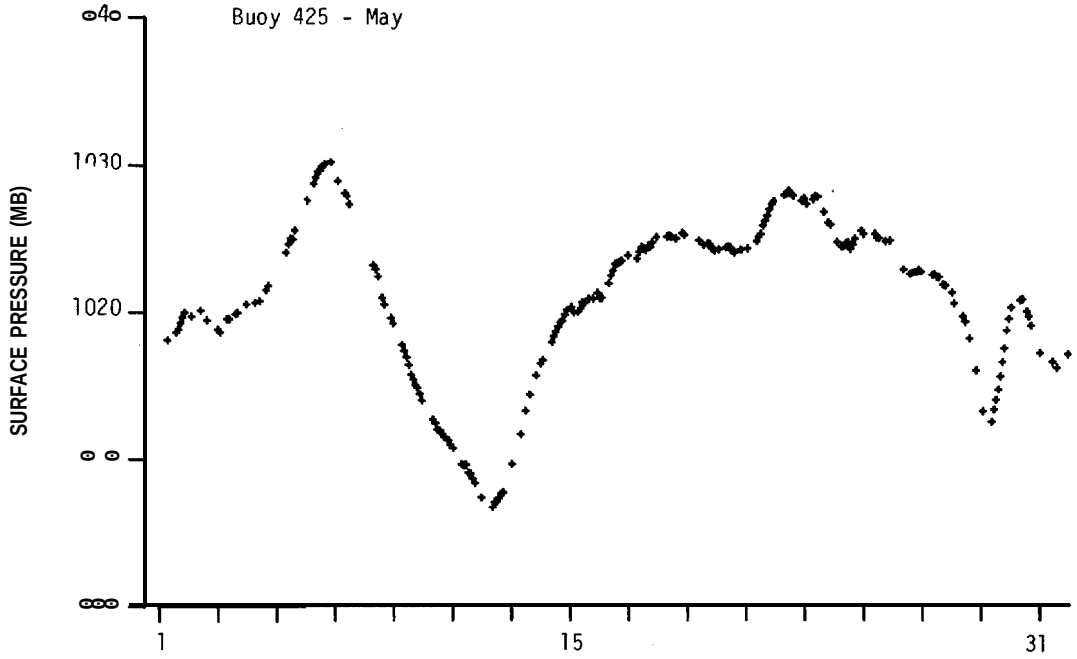

Buoy 1301 - July
72
71
70
LATITUDE
long.
lat.
lat.
long.
172
170
168
166
LONGITUDE
1
15
31

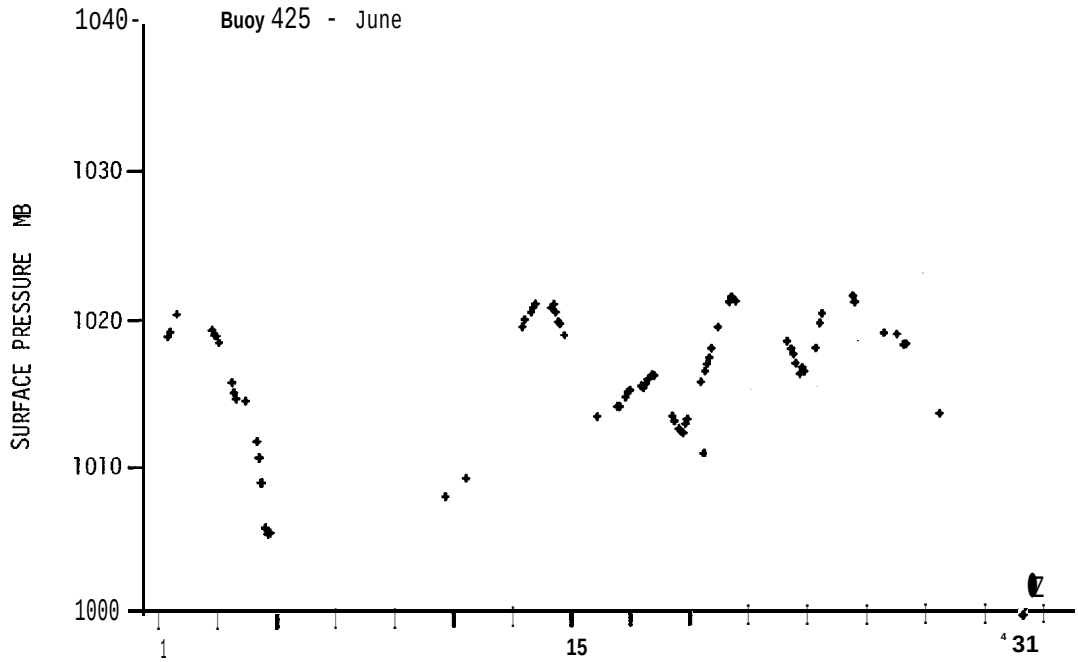
Time Series of Surface Pressure

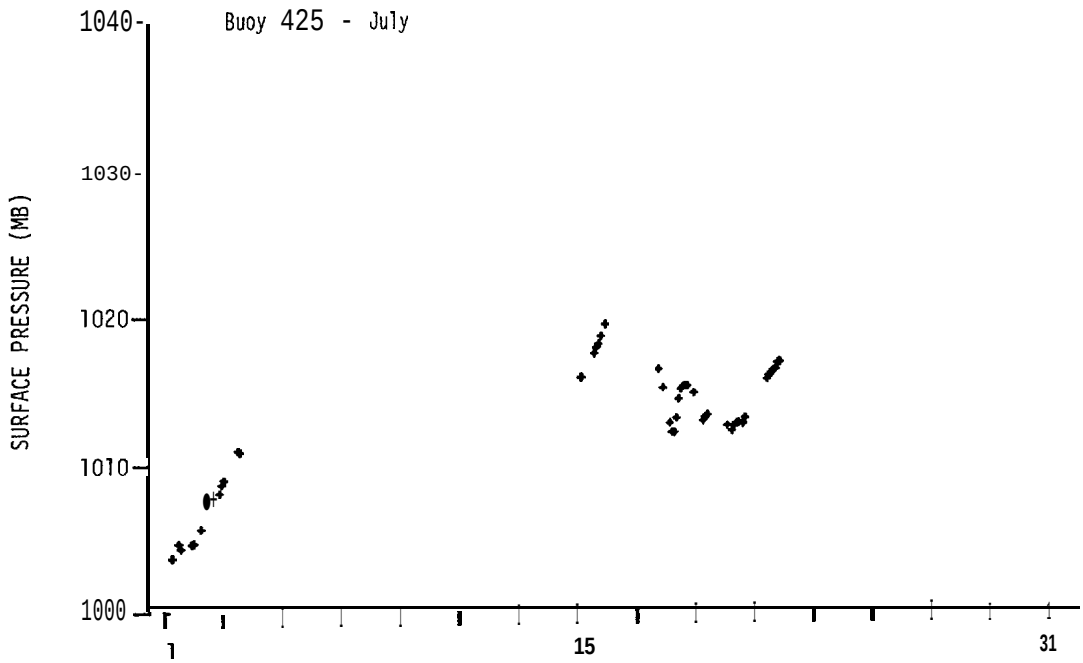
Buoy 425 was instrumented with a Paroscientific Digiquartz pressure transducer to measure atmospheric sea level pressure. This instrument was checked at Barrow to insure correct calibration. Testing of this type of barometer is reported by P. Martin and M. Clarke, A Test of Barometric Pressure and Temperature Measurements from ADRAMS Buoys, AIDJEX Bulletin No. 40 (June 1978, University of Washington).




Buoy 425 - April
SURFACE PRESSURE (MB)
040
030
020
010
000
5
30


Buoy 425 - May
SURFACE PRESSURE (MB)
040
1030
1020
010
000
1
15
31


Buoy 425 - June
SURFACE PRESSURE MB
1040
1030
1020
1010
1000
1
15
31


Buoy 425 - July
SURFACE PRESSURE (MB)
1040
1030
1020
1010
1000
1
15
31